Southern California Priority Corridor
Showcase Program Evaluation

Scoping and Design Project (Showcase Kernel) Evaluation Report

FINAL
VERSION 1.0

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Abbreviations & Acronyms

ATIS	Advanced Traveler Information System
ATMS	Advanced Transportation Management System
AVL	Automatic Vehicle Location
Caltrans	California Department of Transportation
CCTV	Closed-circuit Television surveillance camera
CHP	California Highway Patrol
CM	Configuration Management
CMP	Configuration Management Plan
CMS	Changeable Message Sign
CORBA	Common Object Request Broker Architecture
COTS	Commercial Off-the-Shelf
CTC	California Transportation Commission
CVO	Commercial Vehicle Operations
CW	Corridor-wide
CWATIS	Corridor-wide Advanced Traveler Information System Project
CWATMS	Corridor-wide Advanced Transportation Management System Project
CWCVO	Corridor-wide Commercial Vehicle Operations Project
CWSIP	Corridor-wide Systems Integration Project
CWSPP	Corridor-wide Strategic Planning Project
DOIT	Department of Information Technology
DRI	Caltrans Division of Research & Innovation (formerly NTR)
EAP	Evaluation Activity Plan
EP	Evaluation Plan
FHWA	Federal Highway Administration
FSR	Feasibility Study Report
FTA	Federal Transit Administration
FTE	Full-Time Equivalent (one full-time employee)
GPRA	Government Performance Reporting Act
GUI	Graphical User Interface
HP	Hewlett-Packard
HQIT	Headquarters - Information Technology (division of Caltrans)
IDL	Interface Definition Language
IPR	Intellectual Property Rights
ISSC	Information Systems Service Center (division of Caltrans)
ISTEA	Intermodal Surface Transportation Efficiency Act (of 1991)
ITS	Intelligent Transportation Systems
LACDPW	Los Angeles County Department of Public Works
LADOT	City of Los Angeles Department of Transportation
LAN	Local Area Network
MOU	Memorandum of Understanding
MPO	Metropolitan Planning Organization
MTA	Los Angeles County Metropolitan Transportation Authority
MTBF	Mean Time Between Failure

NDA	Non-Disclosure Agreement
NET	National Engineering Technology Corporation
NTCIP	National Transportation Communications for ITS Protocol
NTR	Caltrans Division of New Technology & Research
OCTA	Orange County Transportation Authority
O&M	Operations and Maintenance
ORB	Object Request Broker (CORBA term)
OS	Operating system (such as Windows™, Unix, Linux, et. al.)
PC	Personal Computer (Windows™-based)
RCTC	Riverside County Transportation Commission
RFP	Request for Proposals
RTP	Regional Transportation Plan
RTPA	Regional Transportation Planning Agency
RWS	Remote Workstation
SANBAG	San Bernardino Association of Governments
SANDAG	San Diego Association of Governments
SCAG	Southern California Association of Governments
SCAQMD	South Coast Air Quality Management District
SCPCSC	Southern California Priority Corridor Steering Committee
TEA-21	Transportation Equity Act for the 21st Century
TMC	Transportation Management Center
USDOT	United States Department of Transportation
VDS	Vehicle Detector Station
VOS	Volume/Occupancy/Speed
WAN	Wide Area Network

Executive Summary

Background

As required by federal law, all Intelligent Transportation System (ITS) projects that receive federal funding must undergo an evaluation to help assess the costs and benefits of ITS. This document is one of 23 reports produced as part of the Southern California ITS Priority Corridor Showcase Program Evaluation to help planners and decision-makers at the federal, state and local levels make better-informed decisions regarding future ITS deployments. This report presents the experiences, costs, and lessons learned from Southern California's Scoping & Design (Kernel) project.

In 1993, the U.S. Department of Transportation designated Southern California as one of four Priority Corridors in which ITS could have particular benefit. Southern California suffers from extreme traffic congestion, limited room for expanding transportation facilities, and above-average air pollution levels. The Southern California Priority Corridor is one of the most populated, traveled, and visited regions in the country, and consists of four adjoining regions:

- Los Angeles County and portions of Ventura County
- Orange County
- San Diego County
- Inland Empire (San Bernardino and Riverside Counties).

The ITS Showcase Program is one of several programs that have been implemented in Southern California's Priority Corridor to help aid mobility and mitigate traffic congestion and its associated environmental impacts. The Showcase Program consists of 17 ITS projects that collectively form a corridor-wide intermodal transportation management and information network between Los Angeles, Orange County, San Diego, and the Inland Empire. Each Showcase project deploys a piece of this corridor-wide ITS network, including regional Advanced Traveler Information Systems (ATIS), regional Advanced Transportation Management Systems (ATMS), and regional and interregional communications infrastructure. Eleven of the projects are regional in nature, while the remaining six are corridor-wide. The Scoping & Design project is one of the six corridor-wide projects within the Southern California Priority Corridor ITS Showcase Program.

The Scoping & Design project is the cornerstone of the Showcase Program. This project performs the preliminary high-level analysis activities to develop the Showcase Architecture, designs and builds the interregional network and Kernels, and helps define the work scopes for the other Showcase projects.

Evaluation Findings, Conclusions, and Recommendations

The Showcase Program is only one part of Southern California's ongoing process to develop and deploy an integrated ITS infrastructure. Specifically, the Scoping & Design project provides all of Southern California with a common foundation on which to continue those ITS developments.

The Scoping & Design project represents an exhaustive effort in planning, analysis, design and implementation. Through this effort, Southern California has reached consensus on a multi-regional ITS architecture that specifies the use of standard software interfaces and CORBA for interregional transportation data exchanges. Critical pieces of that architecture include the interregional Showcase Network and the Kernel software that helps manage the network and provides several necessary network services.

The Scoping & Design contract supported the first eight years of an ongoing evolutionary development of the Kernel software. Through an iterative process, the consultant team successfully developed and delivered a Kernel version 0.1 prototype, a version 0.2/0.3 prototype, and final Kernel version 1.0. The Kernel software resides on four identical and redundant servers. There is one Kernel Server in each of Caltrans' four Southern California Transportation Management Centers (TMCs). Negotiations to use the Caltrans Wide Area Network (WAN) to provide the necessary interregional communications between these servers are ongoing.

Although the Kernels are functional, they are currently in limited use. Due in part to the rapid advancement in software technology between 1995-2001, certain third-party COTS software components used in the Kernel software are no longer supported by their vendor. This presents a dilemma for the Priority Corridor as additional regional systems – being designed and built today using more recent technology – consider how (or whether) to integrate with a Showcase infrastructure based on older technology. As the steward of the four Kernels, Caltrans is working with the Priority Corridor stakeholders to identify and research possible solutions and identify potential funding sources to update the system. Since there will be an ongoing need for occasional system upgrades, particularly as related to software platforms, agencies should consider planning and budgeting for these as part of their routine operations and maintenance (O&M).

The Scoping & Design project also exemplifies the scheduling dilemma facing many ITS projects. Although the actual software development and installation of the Kernels was accomplished in roughly 36 months, the time required by the stakeholders to plan, design, document, and reach consensus on the system amounted to nearly six years. For software projects, this can be an eternity as technology advancements quickly outpace them. To help alleviate schedule impacts, agencies might consider two complementary strategies for managing future ITS projects.

First, split the Design and Build phases into separate contracts or task orders so that planning can take place independent of system development. The Design phase provides

time for stakeholders to reach consensus on needs and system requirements, develop a detailed Concept of Operations, and put in place the necessary institutional agreements to help ensure the system's successful and continued operation once built. Although combining the Design and Build phases into a single Design-Build contract eliminates the burden of executing the Build contract on its own, the cost (i.e., the risk associated with committing to build a system before the needs or institutional issues are fully understood) does not necessarily outweigh this benefit.

Second, agencies should consider planning and deploying their systems in small steps, which can be implemented quickly and do not commit the agency to large technology investments. This approach provides flexibility through the recurring opportunity to reevaluate investment decisions and technology choices after each incremental build.

In summary, the development of the Kernels put in place both a physical and institutional foundation for further ITS development across Southern California. Through this experience, stakeholders from the four Southern California regions have had the opportunity to face and resolve critical institutional issues and establish precedents for the Priority Corridor's future ITS projects. The programming of funds for continued operations and maintenance of Showcase systems demonstrates the Southern California Priority Corridor's commitment to mainstreaming ITS.

1 Introduction

1.1 Purpose and Scope of this Report

As required by federal law[1], all Intelligent Transportation System (ITS) projects that receive federal funding must undergo an evaluation to help assess the costs and benefits of ITS. The information provided in this report is intended to help planners and decision-makers at the federal, state and local levels make better-informed decisions regarding future ITS deployments based on the experiences of Southern California's Scoping & Design (Kernel) project.

This document is one of 23 reports produced as part of the Southern California ITS Priority Corridor Showcase Program Evaluation, and covers only the events and findings resulting from the Scoping & Design (Kernel) evaluation. The complete set of findings from the Showcase Program Evaluation are found in the following collection of documents:

Document Type/Title	Date	Document Number
17 Individual Project Evaluation Reports		
Corridor-wide ATIS Project Report (Draft)	4/25/2003	65A0030/0033
Corridor-wide ATMS Project Report	TBD	
Corridor-wide CVO Project Report	TBD	
Corridor-wide Rideshare Project Report	TBD	
Corridor-wide Strategic Planning Project Report	10/29/2002	65A0030/0028
Fontana-Ontario ATMIS Project Report	TBD	
IMAJINE Project Report	3/17/2003	65A0030/0029
IMTMC Project Report	TBD	
InterCAD Project Report	4/2/2003	65A0030/0030
Kernel Project Report	**5/30/2003**	**65A0030/0031**
LA ATIS Project Report	TBD	
Mission Valley ATMIS Project Report	TBD	
Mode Shift Project Report	TBD	
OCMDI Project Report	TBD	
Traffic Signal Integration Project Report	TBD	
Transit Mgt System Project Report	TBD	
TravelTIP Project Report	TBD	
5 Cross-Cutting Evaluation Reports		
System Performance Cross-Cutting Report	TBD	
Costs Cross-Cutting Report	TBD	
Institutional Issues Cross-Cutting Report	TBD	
Information Management Cross-Cutting Report	TBD	
Transportation System Impacts Cross-Cutting Report	TBD	
Final Summary Evaluation Report		
Showcase Program Evaluation Summary Report	TBD	

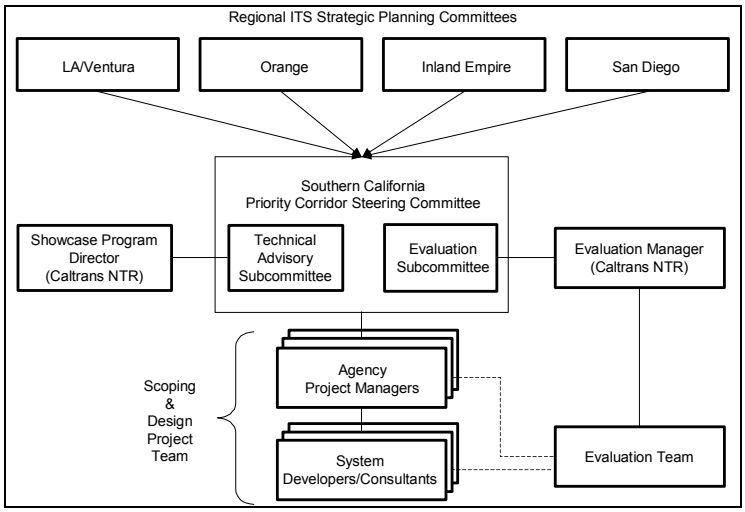
"TBD" indicates a future deliverable that is not yet available.

1.2 Evaluation Design and Approach

The findings outlined in this report are based on over four years of personal observations at project meetings, reviews of released project documents and agency memos, analysis of collected quantitative data, as well as formal and informal interviews and discussions with project partners.

The evaluation is responsive to the needs and suggestions of the Priority Corridor's Evaluation Subcommittee, which reports to the Priority Corridor's Steering Committee. As shown in Exhibit 1, both committees are comprised of stakeholders from the federal, state, and local levels.

Exhibit 1 – Management Structure and Organization of the Showcase Program



The Steering Committee's member agencies reflect wide representation from the region in terms of federal and state highway agencies, public safety, cities and counties, transit, air quality and regional planning entities, including:

- California Highway Patrol (CHP)
- Caltrans, Division of Traffic Operations (headquarters)*
- Caltrans, District 7*
- Caltrans, District 8*
- Caltrans, District 11*
- Caltrans, District 12
- City of Irvine*
- City of Los Angeles Department of Transportation (LADOT)
- City of San Diego
- Federal Highway Administration (FHWA)*
- Federal Transit Administration (FTA)
- Los Angeles County Metropolitan Transportation Authority (MTA)
- Orange County Transportation Authority (OCTA)

- Riverside County Transportation Commission (RCTC)
- San Bernardino Association of Governments (SANBAG)
- San Diego Association of Governments (SANDAG)
- South Coast Air Quality Management District (SCAQMD)
- Southern California Association of Governments (SCAG).

* Indicates an Evaluation Subcommittee member

The Showcase Program's Evaluation Design is based on a set of evaluation Goals and supporting Objectives and Measures that were developed by the Evaluation Team in partnership with federal, state and local stakeholders, and documented in the "Showcase Program Evaluation Approach" in 1998. Each individual Showcase project is evaluated based on an applicable subset of these Goals, Objectives, and Measures in order to help ensure that summary evaluation results can be aggregated from across the multiple Showcase project evaluations. The Showcase Program's five evaluation Goals include:

- Evaluate System Performance
- Evaluate Costs
- Evaluate Institutional Issues and Impacts
- Evaluate the Use and Management of Transportation/Traveler Information
- Evaluate Transportation System Impacts.

As the Scoping & Design project evolved, project-specific refinements to the evaluation design were documented in a high-level Evaluation Plan (EP) and a detailed Evaluation Activity Plan (EAP). In general, the EP describes the project and/or system under evaluation, and lays the foundation for further evaluation activities by developing consensus among the Evaluation Subcommittee and project partners as to which of Showcase's evaluation Goals, Objectives, and Measures best apply to the project.

As the project matured, and after the EP had been approved, an EAP was developed to plan, schedule, and describe specific activities (interviews, surveys, etc.) and step-by-step procedures for conducting the evaluation. Data collection began after both plans had been reviewed and subsequently approved by the Evaluation Subcommittee and the project's partners.

1.3 Organization of this Report

The Scoping & Design Evaluation Report provides a background description of the Southern California Priority Corridor and the transportation challenges it faces. This is followed by descriptions of the Showcase Program and the Scoping & Design project, including a detailed

technical description. The evaluation itself is subdivided and ordered into the four topic areas described below:

System Performance — provides important benchmark information regarding system availability, reliability, scalability and compatibility. The evaluation quantifies those items and could be used to identify needed improvements and help develop specifications for future systems.

Cost — provides important benchmark information regarding funding sources, software licensing, development costs, costs to re-deploy elsewhere or expand the system, and operations and maintenance (O&M) costs. This report includes an estimate of how much it might cost to re-deploy the Kernel "from scratch" elsewhere in the State, and also looks at the incremental costs for integrating additional partner agencies and/or traveler information kiosks into the existing system.

Institutional Impacts — provides important information regarding the administrative, procedural and legal impacts resulting from the deployment of the Kernel. Such impacts include changes in operator workloads, responsibilities and job turnover rates, as well as changes and limitations of agency-wide policies, procedures and guidelines.

Transportation & Traveler Information Management — provides important benchmark information on system usage and user acceptance (by agency operators). This report provides both quantitative and qualitative findings on those items and can be used to identify user demand, needed improvements and potential areas of future growth.

Since the Kernel is an enabling technology that supports other Showcase systems, the Evaluation Subcommittee and the project partners concurred that an evaluation of Transportation System Impacts (Evaluation Goal 5) did not apply and was not warranted.

This report concludes with a summary of findings and recommendations.

1.4 Privacy Considerations

Some of the information acquired in the interview and discussion process could be considered sensitive and has been characterized in this report without attribution. The Evaluation Team has taken precautions to safeguard responses and maintain their confidentiality. Wherever possible, interview responses have been aggregated during analysis such that individual responses have become part of a larger aggregate response. The names of individuals and directly attributable quotes have not been used in this document unless the person has reviewed and expressly consented to its use.

1.5 Constraints & Assumptions

The Scoping & Design evaluation is subject to the following constraints and assumptions:

- The project's consultant was not required to disclose actual project expenses, so the project's cost is based on the budget stipulated in the Scoping & Design contract and its amendments. The budget reflects the expenses and costs for services paid by the client agency, but not necessarily the actual detailed costs for goods and services comprising the project.

1.6 Project Background

1.6.1 The Southern California Priority Corridor

In 1993, the U.S. Department of Transportation designated Southern California as one of four Priority Corridors in which Intelligent Transportation Systems (ITS) could have particular benefit. The Southern California Priority Corridor, illustrated in Exhibit 2, is one of the most populated, traveled, and visited regions in the country. Roughly two-thirds of the state's population – about 20 million people – resides in or around the Southern California Priority Corridor. It suffers from extreme traffic congestion, limited room for expanding transportation facilities, and above-average air pollution levels.

The Southern California Priority Corridor consists of four distinct regions that correspond with the four Southern California Caltrans districts:

- Los Angeles/Ventura (Caltrans District 7)
- Orange County (Caltrans District 12)
- San Diego (Caltrans District 11)
- Inland Empire (Caltrans District 8)

Exhibit 2 – The Southern California Priority Corridor and Vicinity

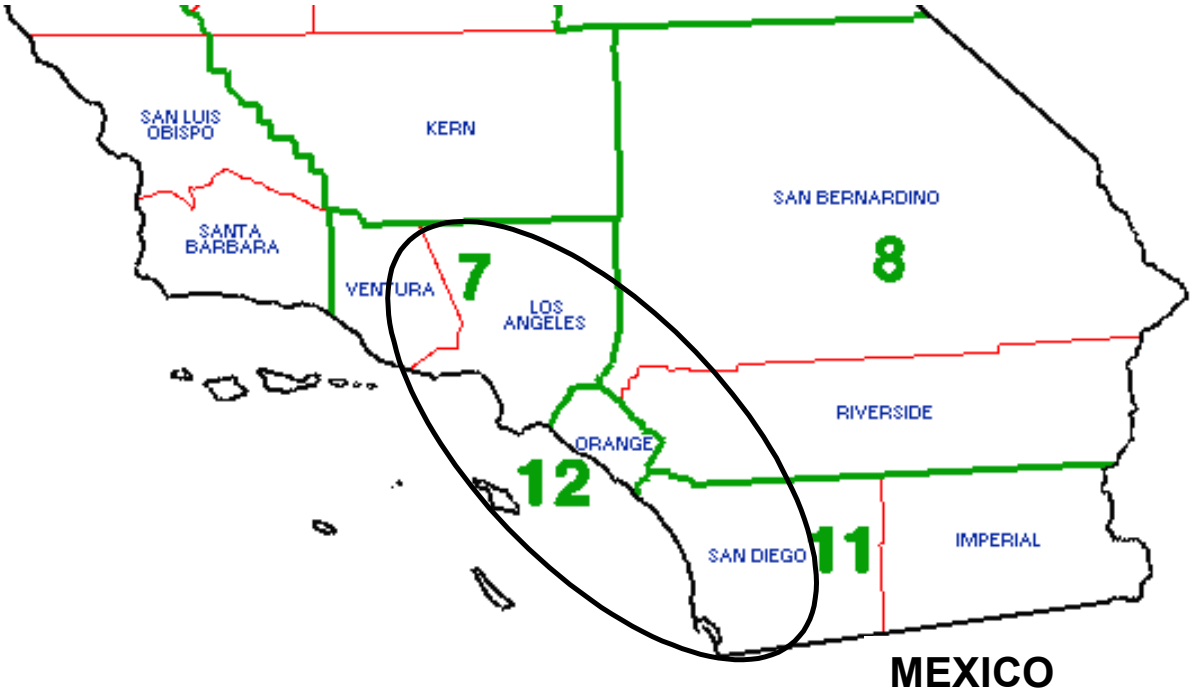


Exhibit 3 – Population and Number of Registered Vehicles by County

County	Population[2] (as of 7/1/2001)	Registered Vehicles[3]* (as of 12/31/2000)	Caltrans District
Los Angeles	9.7 million	6.2 million	7
Orange	2.9 million	2.1 million	12
San Diego	2.9 million	2.1 million	11
San Bernardino	1.8 million	1.1 million	8
Riverside	1.6 million	1.1 million	8
Ventura	0.8 million	0.6 million	7
Imperial	0.15 million	0.1 million	11
Total	**19.85 million**	**12.7 million**	

*Includes autos, trucks, and motorcycles. Trailers not included.

1.6.2 The Southern California Priority Corridor's ITS Showcase Program

The ITS Showcase Program is one of several programs that have been implemented in Southern California's Priority Corridor to help aid mobility and mitigate traffic congestion and its associated environmental impacts.

Exhibit 4 lists the 17 ITS projects, by region, that comprise the Southern California Priority Corridor ITS Showcase Program. These projects collectively form a corridor-wide intermodal

transportation management and information network between Los Angeles, Orange County, San Diego, and the Inland Empire. Eleven of the projects are regional in nature, while the remaining six are corridor-wide in scope. Eight of the projects, including Scoping & Design, were fast-tracked and designated "Early Start" projects because of their importance as enabling technology, base infrastructure and potential to act as role models for the rest of the Showcase Program.

Exhibit 4 – The 17 Showcase Projects and their Status as of March 2003

Project	RFP Issued	Contractor Selected	Contract Executed	Project Underway	Project Complete
Corridor-wide					
Scoping & High Level Design*	✓	✓	✓	✓	✓
Strategic Planning/Systems Integration	✓	✓	✓	✓	✓
CVO🗎					
ATIS	✓	✓	✓	✓	✓
ATMS🗎					
Rideshare	✓	✓	✓	✓	✓
Los Angeles Region					
IMAJINE*	✓	✓	✓	✓	✓
Mode Shift*	✓	✓	✓	✓	
LA ATIS	✓	✓	✓	✓	
Inland Empire Region					
Fontana-Ontario ATMIS	✓	✓	✓	✓	
Orange County Region					
TravelTIP*	✓	✓	✓	✓	✓
OCMDI	✓	✓	✓	✓	✓
San Diego Region					
InterCAD*	✓	✓	✓	✓	✓
Mission Valley ATMIS*	✓	✓	✓	✓	
IMTMS/C (ATMSi)*	✓	✓	✓	✓	
Traffic Signal Integration (RAMS)	✓	✓			
Transit Management System*	✓	✓	✓	✓	

* Indicates an "Early Start" project.
🗎 CWCVO and CWATMS do not yet have approved workplans.

2 Project/System Technical Description

The Scoping & Design project accomplishes three major goals for the Showcase Program:

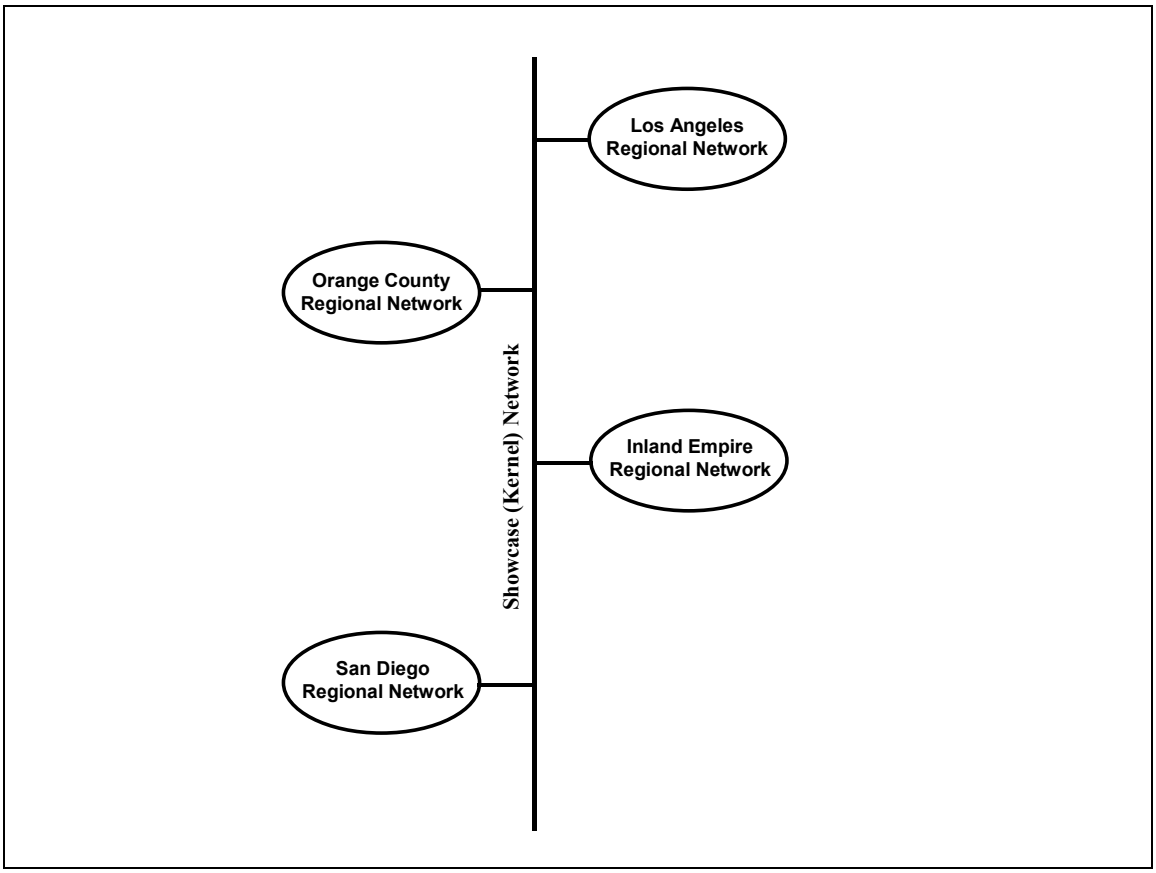
- Develops the high-level Showcase Architecture
- Designs and builds the network Kernel(s)
- Helps define the work scopes of the other Showcase projects.

The vision of the Southern California ITS Priority Corridor Steering Committee is to significantly improve the safety, efficiency, and environmental impacts of the region's intermodal transportation system through the application of advanced transportation technologies and integrated management systems. The Kernels and the Showcase Network support this vision by enabling transportation agencies throughout the corridor to exchange data and coordinate services interregionally. One very important and lasting benefit from the Kernels is the ongoing, productive working relationships and interagency agreements among the diverse transportation organizations in the corridor.

The Kernels and the Showcase Network enable transportation agencies to exchange data and coordinate services, particularly at regional boundaries. The system effectively brings together existing transportation management facilities from throughout the corridor and enables them to exchange information for better-coordinated activity between their jurisdictions.

The Scoping & Design contract links the regional Showcase projects together into a single corridor-wide system by establishing an interregional communications backbone and providing associated "common services." Regional projects in Orange County, Los Angeles, San Diego and the Inland Empire will use this communications backbone to share and exchange their data interregionally. The "common services" provide the tools that enable regional centers to log on/off of the network, view a "white pages" and "yellow pages" of data that is available on the network, as well as publish and subscribe to available traffic "event" information. In addition, the Kernel monitors the communications system and alerts regional centers to system failures. Although the Kernel makes these "common services" available, it is up to the developers of the regional systems to design and implement their software to make use of these services. None of the Showcase-funded regional systems that have been built to-date utilize all of the services.

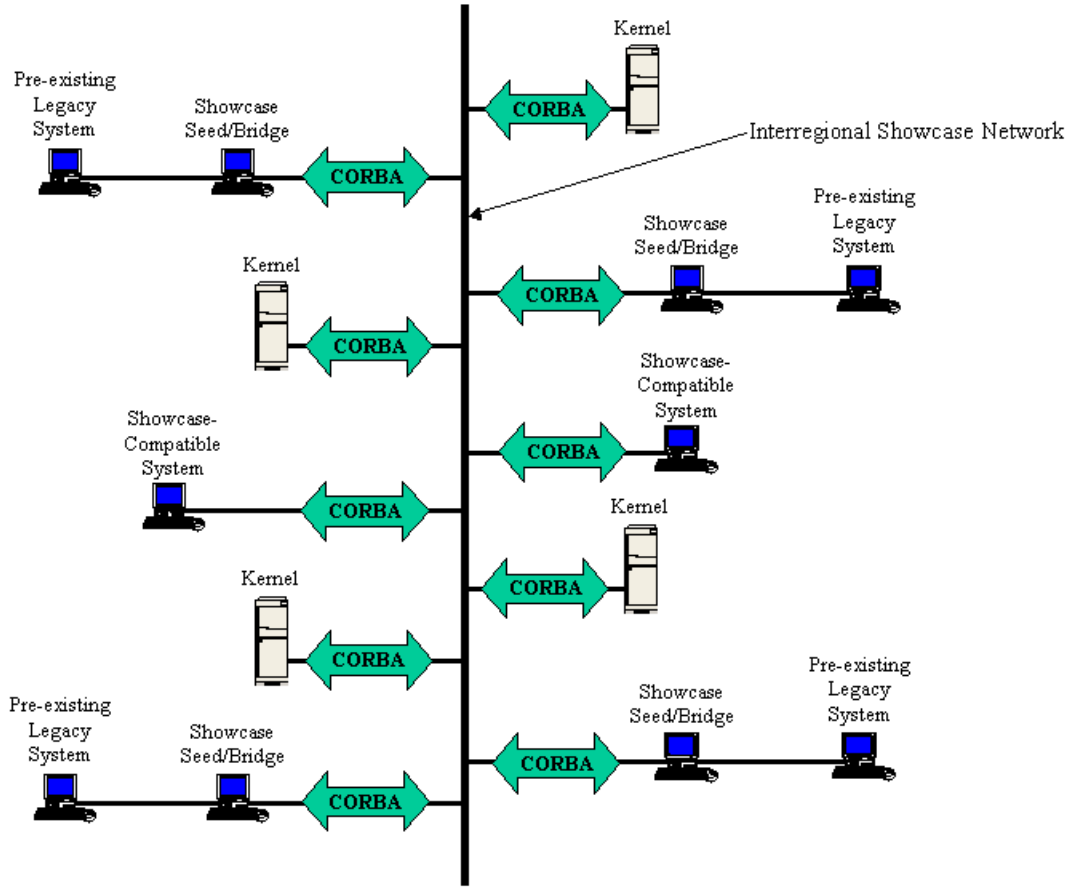
Exhibit 5 – Conceptual View of the Interregional Showcase Network



This report describes the Showcase Architecture in progressively greater detail starting with Exhibits 5, which shows the Showcase Network's interregional backbone connecting the four regional ITS networks into one corridor-wide system.

Exhibit 6 goes into slightly more detail, but still provides only a simplified view of the communications between centers and Kernels. Contrary to what is shown in Exhibit 6, centers do not integrate directly to the interregional backbone, but rather connect to a regional network that is tied to the backbone. Under the Showcase Architecture, both new systems and pre-existing legacy systems are enabled to communicate with each other using standardized Showcase objects and commands, which are contained and documented in Showcase's CORBA-based Interface Definition Language (IDL). The legacy systems require "Seeds" that act as translators to convert their unique data structures to Showcase objects and vice versa. Newly built "Showcase-compliant" systems that inherently use Showcase objects do not require Seeds. Showcase objects are then passed between systems using CORBA technology. The four redundant Kernel servers (there is one in each region of the Priority Corridor) provide network users with a suite of common services, which are described in more detail below.

Exhibit 6 – High-Level Showcase Architecture



Common network services provided by the Kernels include:

Security – This service authenticates a user on the network, and allows the user to be assigned privileges and priorities to receive information and control devices.

Naming – This service provides a "white pages" style directory of the other agencies on the network and the data that each provides. This effectively provides the user with a list of data sources from which to select.

Trader – This service is the "yellow pages" complement to the Naming service.

Publish & Subscribe (P&S) – This service allows agencies to select certain data to "publish" out onto the network based on criteria such as mode, location, and severity. This service is generally used for sharing traffic advisories and event information. The agencies that wish to receive this data can "subscribe" by setting their filter criteria accordingly. In this way, P&S allows agencies to control what information they release, as well as filter and receive only the data that is important to them. Whereas P&S is the method used to distribute asynchronous (i.e., non-continuous) data such as events, a direct peer-to-peer (non-P&S/non-Kernel) connection is used to distribute continuous data such as traffic speeds and transit vehicle locations.

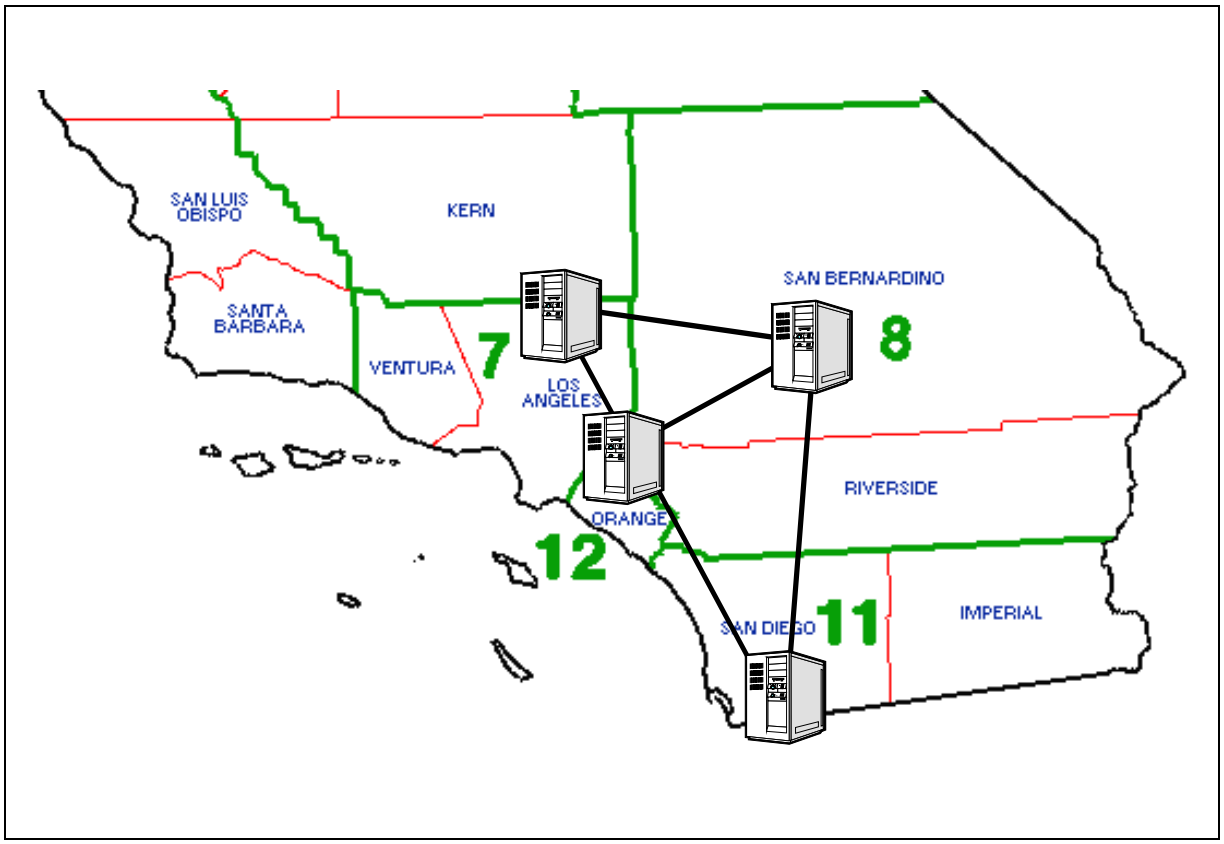
Query – The query service allows an agency to search through data that has been published or archived by other agencies on the network in order to find particular items of interest. For example, a query could be used to find all of the traffic incidents in the last six months that were of major severity. Each agency, however, can limit which of its data is accessible to queries by using the service's built-in security settings.

Location Translation – The Kernel provides software routines that agency centers can utilize to convert location coordinates between "State Plane," "Route/Postmile," and "Latitude/Longitude."

Time Synchronization – The Kernel provides a common clock (based on the Network Time Protocol or NTP) to which centers can synchronize themselves. This is essential for coordinating time-sensitive events such as timing-out traffic advisories and prioritizing system requests.

Failover – The Kernel software resides on four identical and redundant servers that are distributed throughout the corridor. There is one server in each of the four Southern California Caltrans Transportation Management Centers (TMCs) in Districts 7, 8, 11 and 12. When a regional system logs onto the network, it must contact and be "connected" to one of these Kernel servers. If that Kernel server fails for any reason, the regional system must detect the failure and "reconnect" to one of the remaining three servers on the network.

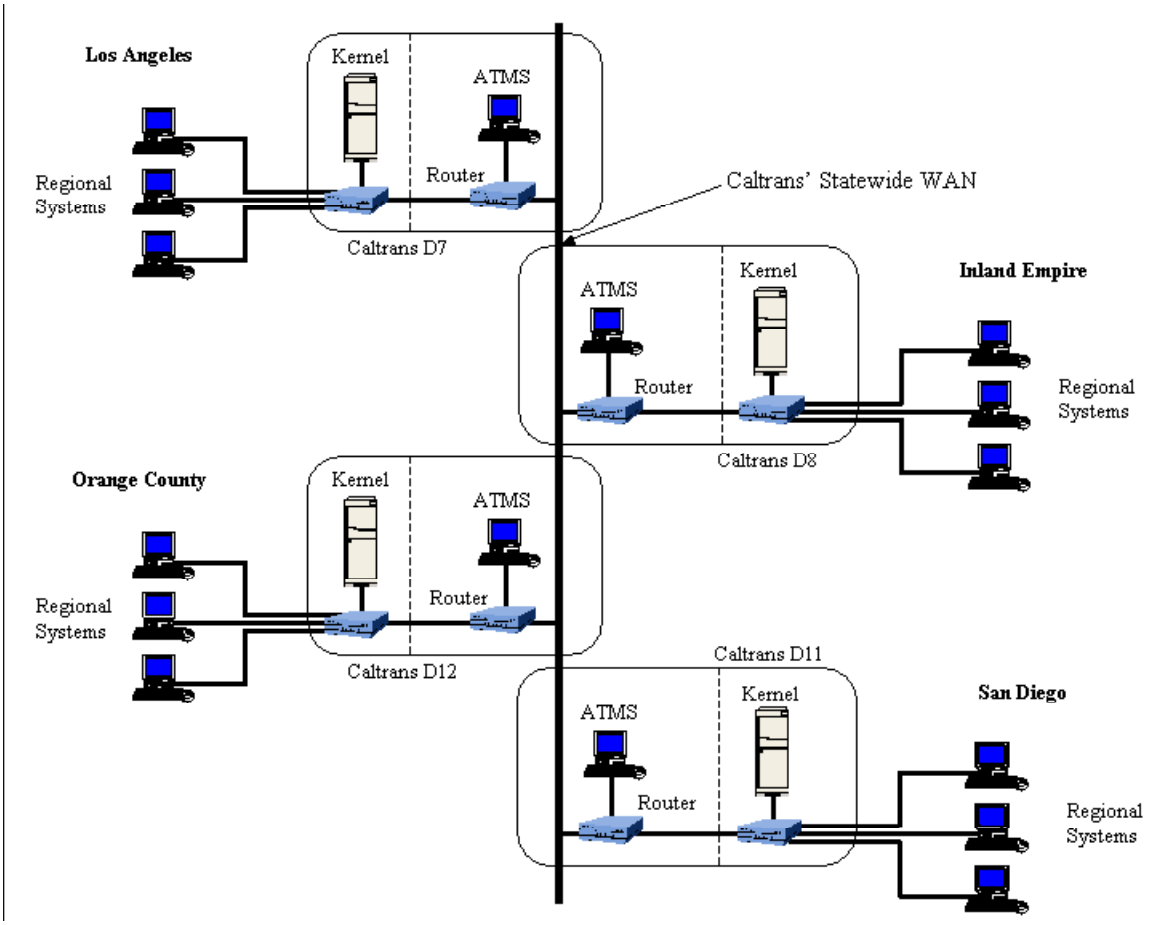
Exhibit 7 – Geographic Distribution of the Showcase Kernel Servers



The physical interregional backbone connecting the Kernels is currently being provided by Caltrans' statewide Wide Area Network (WAN), which consists of Caltrans-owned fiber and additional leased lines. Local agencies connect to the Caltrans WAN by installing or leasing lines that run from their offices to a hub at the nearest Caltrans TMC.

Exhibit 8 shows a conceptual design of the Showcase Network in which regional networks are formed around each of the four Caltrans TMCs. Rounded boxes indicate the Caltrans TMCs and dashed lines separate pre-existing legacy systems from Showcase components. In general, leased communications lines provide the connections from the various systems in the region to a hub at the nearest Caltrans TMC. This hub provides secure, controlled access to the Caltrans WAN, which acts as Showcase's interregional backbone. The various regional systems might include legacy systems with Seeds as well as newer Showcase-compliant systems that don't need Seeds.

Exhibit 8 – Conceptual Physical Design of the Showcase Network



3 System Performance Evaluation

3.1 The Project/System Development Process and Timeline

The Scoping & Design project used a systems engineering process to help scope out the Showcase Program and develop the interregional network Kernel.

The Scoping & Design project represents roughly eight years of program planning, consensus building, and system development.

A Request for Proposal (RFP) was published in January 1995 to hire a consultant to help scope out and plan the Showcase Program, analyze alternative architectures and technologies, and prepare a single high-level system design compatible with the National ITS Architecture. Rockwell Transportation Systems (later Odetics ITS, then Iteris) and National Engineering Technology (NET) were selected as a team to perform the work.

Phase 1 (Scoping) occurred between June 1995 and March 1997. It established the overall scope of the Showcase Program and identified specific "Early Start" projects to build key components and act as prototypes or role models for the remaining projects. The Phase 1 deliverables, and their final completion dates (where available), are listed below:

- Task A – Detailed Scope and Schedule
- Task 1 – "Early Start" Candidate Report
- Task 2 – System Architecture Report (November 1996)
- Task 3 – Implementation Plan (March 1997)
- Tasks 4/5 – Federal Funding Proposal/Presentation (December 1996)
- Task 6 – Updated Workplan and Schedule.

Phase 2 (High Level Design) began in September 1996 and developed the Kernel Prototype (later referred to as Kernel version 0.1) to support San Diego's InterCAD Early Start project. Phase 2 deliverables included:

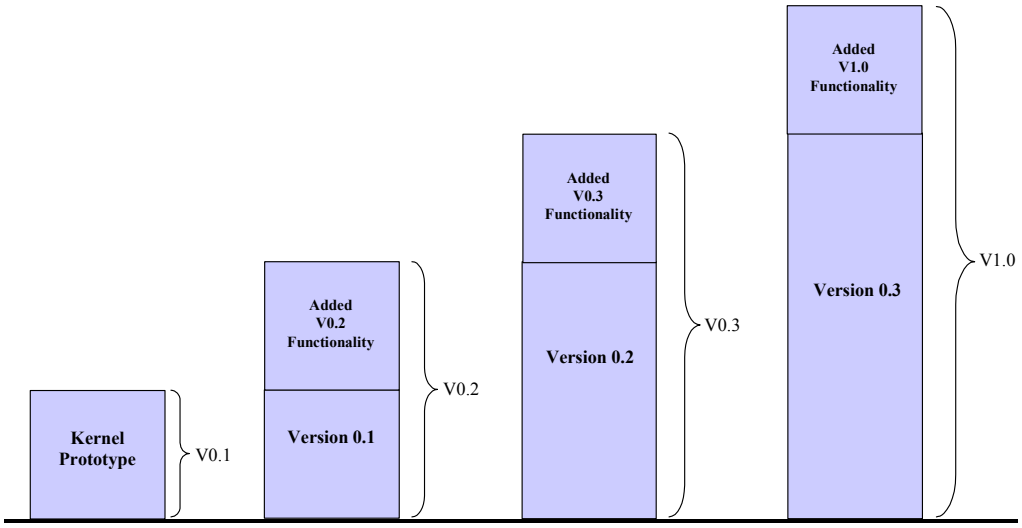
- Task 7 – User Requirements Document (July 1997)
- Task 8 – Kernel-to-Early Start Functional Interface Requirements Document (July 1998)
- Task 9 – Candidate Architectures Trade-Off (July 1997)
- Task 10 – High Level Systems Design Report/Working Paper (April 1998)
- Task 11 – Prototype Implementation (v0.1) and Kernel Design Document (November 1998)
- Task 12 – Lancaster/Palmdale Corridor Expansion Presentation (September 1998)
- Task 13 – Tasks 2-6 Reproduction and Distribution.

Phase 2a began in October 1998 to begin development of Kernel version 0.2, which was to add specific ATIS functionality to the Kernel software to support Orange County's TravelTIP project. Phase 2a transitioned to Phase 3 in May 1999, and the Phase 2a deliverables included:

- Task RP1.1/1.2.1 – Prototype V0.2 Functional Specification (March 1999)
- Task RP1.2.2 – Prototype V0.2 Disposition Matrix (March 1999)
- Task RP1.3.1 – Expersoft to Iona Technical Memorandum (March 1999).

Phase 3 continued the development of the version 0.2, version 0.3, and version 1.0 Kernels. Version 0.3 was to add specific ATMS functionality to the Kernel software to support Los Angeles' IMAJINE project, while version 1.0 would be the final "networked" version. Each successive version of the Kernel software built on previous versions by refining the design and adding functionality as depicted in the exhibit below.

Exhibit 9 – The Progression of Kernel Builds



The Steering Committee approved a plan in mid-1999 to combine the delivery of versions 0.2 and 0.3 to help the project save time (primarily in version 0.2 testing) and stay on schedule. Conceptually, the development still followed the progression shown in Exhibit 9, though no stand-alone version 0.2 was ever delivered. The combined version 0.2/0.3 Kernel underwent acceptance testing in December 1999 and was accepted by the Steering Committee at its April 2000 meeting. Kernel version 1.0 successfully passed its "bench test" in November 2000, after which began the process of installing and integrating the system into the four Caltrans TMCs. Final integration testing was completed in November 2001, at which time Kernel v1.0 was formally accepted and available for operation.

Phase 3 deliverables included:

- Tasks 14/15 – Develop and Deliver Kernel Version 0.2 Prototype
- Tasks 16/17 – Develop and Deliver Kernel Version 0.3 Prototype
  - ⇒ Task 16.2 – Kernel Version 0.3 Functional Specification (August 1999)
  - ⇒ Task 16.4 – Kernel Version 0.2/0.3 Prototype Integration and Unit Test Results (February 2000)
  - ⇒ Task 17.1 – Updated (as-built) Kernel Version 0.2/0.3 Functional Specification (March 2000)
  - ⇒ Task 17.4 – Showcase Kernel Delivery Information Document (March 2000)
  - ⇒ Task 15/17 – Updated Phase 2 Kernel Interface Requirements (November 2001)
- Task 18 – Kernel Version 1.0 User Requirements (March 2000)
- Task 19 – Communications High Level Design (July 2000)
- Task 20 – Implementation Phasing Plan (May 2000)
- Task 21 – Training and Acceptance Testing of Kernel Version 0.2/0.3 Prototype
  - ⇒ Task 21.1/21.2 – Kernel Version0.2/0.3 Acceptance Test Plan (November 1999)
  - ⇒ Task 21.2 – Kernel Version 0.2/0.3 User/System Administration Manual (June 2000)
- Task 22 – Develop, Deploy and Test Kernel Version 1.0 with Network
- Task 24 – Six-Month O&M/Warranty Period
- Task 25 – Install and Support Kernel Prototype (v0.2/0.3) in San Diego County
- Task 26 – Acceptance Testing of Version 1.0 Kernel (November 2001).

The Scoping & Design contract was closed out by SANDAG in November 2002. The delay between Kernel version 1.0 Acceptance Testing and contract close-out was due in part to disagreement by some stakeholders over the accuracy and completeness of the final (as-built) Kernel Interface documentation. The matter has not been fully resolved because validating the documentation could require a significant software reverse-engineering effort.

3.2 System Reliability, Availability, Compatibility, and Scalability

This section focuses primarily on the system performance of the Kernel network, and addresses reliability, availability, compatibility, and scalability.

3.2.1 System Reliability and Availability

The system has successfully demonstrated its ability to perform its functions under controlled tests.

The four Kernel servers were installed at the four Southern California Caltrans TMCs, and have been operational there since December 1, 2001. In system tests, the Kernels successfully demonstrated their ability to perform their functions and meet their specified requirements. Technical support staff at each of the Caltrans TMCs report that there has been no evidence of any system failures since the Kernels were installed. The Kernels are processing limited data at

this time since only Los Angeles' IMAJINE system (one of the regional Showcase projects) is currently integrated with the Kernel version 1.0 software (Please see the IMAJINE Evaluation Report for more details).

3.2.2 Compatibility

There are no indications of any system incompatibilities. In fact, the Kernels have proven an ability to transfer data between legacy and COTS systems across agencies.

Compatibility is the ability of two or more systems or components to perform their required functions while sharing the same hardware or software environment. There have not been any system failures or anomalies experienced during the 13 months of this study that would indicate an incompatibility with the existing software/hardware environment.

3.2.3 Scalability

Although the Kernel architecture was designed to be scalable, a problem with the backwards-compatibility of one software component threatens this scalability.

Scalability describes the extent to which system usage can grow without sacrificing system performance or requiring architectural or technology changes. In this study, system usage is defined in terms of data (object) throughput and is measured in units of objects per second (Obj/sec). System usage could increase due to an increased utilization of existing centers or because of the addition of new centers onto the Kernel network. The factors that influence the system's scalability include:

- Hardware capability
- Software design.

There are usually about 80-100 incidents per day in each of the Priority Corridor's four regions. On bad days involving rain or high winds, this number can jump to 200 incidents per region. If information regarding all of these incidents were to be exchanged through the Kernel, the rate of data transfer would average roughly:

4 regions x 200 incidents / region = 800 incidents (objects)

800 incidents (objects) / 12 hour period = 67 incidents (objects) per hour

67 incidents (objects) per hour = 0.02 incident objects per second.

The Kernel's P&S service has shown in tests to handle 40-45 objects per second, or about 2000 times as many as would need to be processed on a particularly bad traffic day. The capacity to

accommodate current data exchange is accompanied by significant capacity for growth, and also provides redundancy should a server failure occur.

Communications bandwidth between the Kernels does not pose a bottleneck. The Caltrans WAN provides 1.5 Mbps of bandwidth, and is leased from a private telecommunications provider. Even if system usage threatened to exceed this limit, additional bandwidth could be leased or purchased from this telecommunications provider.

Although the system architecture is conducive to scaling, the unforeseeable obsolescence of one of the Kernel software's third-party COTS software components presents a dilemma. The Kernel v1.0 (as well as TravelTIP and IMAJINE) software utilizes Iona's Orbix 3.1 CORBA Object Request Broker (ORB) software component, and Iona discontinued the support of Orbix 3.1 when it released its latest Orbix 2000 product. This typically would not be a major issue; however, Orbix 2000 is based on newer technology and is not backwards-compatible with the earlier versions of Orbix. Although Orbix 3.1 still works, those regional systems that are still under development are reluctant to build their systems using an out-dated technology. The result is that the newer systems developed using Orbix 2000 would not be interoperable with the systems that use Orbix 3.1. The Priority Corridor is currently identifying and researching its options. Some of these options include:

- *Upgrade the existing systems (the Kernel, TravelTIP, IMAJINE) to Orbix 2000*

  Caltrans has been researching this option, and has discovered that this could involve significant cost and effort. The current Kernel software runs on Hewlett-Packard (HP) K360 servers with the HP-UX 10 operating system, but Orbix 2000 will not run on these machines. This presents two sub-alternatives:

  ⇒ If the Kernel services continue to be hosted on centralized Kernel Servers, this will require the purchase of new server hardware with a more up-to-date operating system (the current hardware will not accommodate a newer OS). These costs are in addition to the costs of actually modifying the software for the Kernel, TravelTIP and IMAJINE. However, this option will result in an up-to-date infrastructure to which the regional systems can integrate.

  ⇒ However, as has always been the long-term plan, the Kernel services could be distributed so that they reside within the regional systems themselves. This would avoid the need to purchase new Kernel server hardware, but it would require modification or upgrade to the regional systems that have been completed (TravelTIP and IMAJINE) or are currently under development (LA/Ventura ATIS, Mission Valley ATMIS, and the Fontana-Ontario ATMIS).

- *Leave the Kernel software as is (using Orbix 3.1), use Orbix 2000 in the current regional systems, and develop "patches" to essentially make the Orbix 2000 systems interoperable with their Orbix 3.1 colleagues.*

  Although this idea has been raised, neither the consultants nor IONA have presented any indication that "patching" Orbix 2000 to Orbix 3.x is possible, let alone economically viable.

3.3 Impact of Showcase Integration on Project Deployment and System Performance

3.3.1 Impact of Scoping & Design and the Kernel on other Showcase Projects

The Scoping & Design Project developed standard software interfaces to help ensure system-to-system interoperability

The Kernel is at the heart of the Showcase Architecture. Regional systems that wish to exchange data interregionally must connect to the Kernel. Tasks 15 and 17 of the Scoping & Design project document the Kernel's software interfaces (also referred to as IDL) so that the regional projects can design their software accordingly. These interfaces essentially set the ground rules for how the various regional systems can communicate with each other. It is imperative that the interface information contained in the Task 15/17 documentation be kept accurate and accessible to all system development teams in order to make possible the corridor-wide interoperability of the regional Showcase systems. This has been a particular strength of the program.

Delays with the Kernel contributed to delays of several regional Showcase projects

The Scoping & Design project – specifically, the development of the Kernels – experienced delays for several reasons, including:

- Delayed release of Iona's Orbix ORB for the HP platform
- "Y2K" and California's temporary moratorium on technology purchases and installations
- Longer than expected negotiations regarding use of the Caltrans WAN by external agencies
- Concurrent projects/System developments

One of the Kernel's delays is attributed to the later than expected release of the Orbix ORB for the HP platform. All of Showcase's software (Kernel's and regional systems) is based on CORBA and the use of third-party COTS software components called Object Request Brokers (ORBs). Several vendors produce and sell ORBs. Through a trade-offs analysis of several ORB vendors and products, the Priority Corridor elected to use the Orbix ORB produced by Iona. Iona, however, prioritized the release of its ORB on other software platforms (such as Windows) ahead of HP based on overall customer demand. Once Iona released the HP version of its ORB, the Kernel development team was able to finalize the version 0.3 software and begin "bench testing."

Another contributor to delay was fear over the "Y2K bug," or the inability of software systems to handle the date rollover to 1/1/00. On 17 February 1999, California's Governor Davis took a preemptive step and declared a moratorium on the purchase and/or installation of any computer systems (hardware or software) not related to Y2K risk mitigation. The period of the moratorium included February 1999 through July 1, 2000 and applied to all Departments within the State of California, including Caltrans. This moratorium prevented the Kernels from being installed at the Caltrans TMCs until after July 1, 2000.

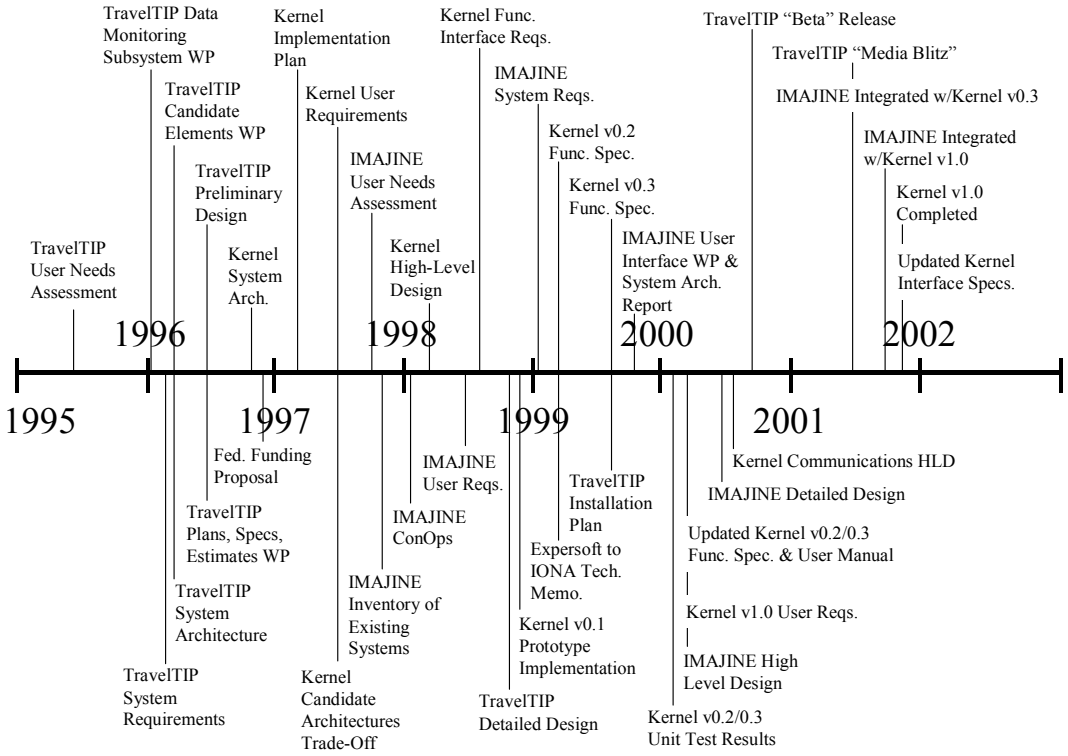
The Priority Corridor approached Caltrans' Information Systems Service Center (ISSC) group in November 1999 regarding use of the statewide WAN as Showcase's "interregional communication backbone." ISSC was interested in helping, and between February and April 2000, the Priority Corridor conducted a Communication Roundtable and developed a Communications Requirements document to explain its network-related needs. The Requirements document was submitted to ISSC on May 2, 2000. ISSC responded by May 26 indicating that the Requirements document was satisfactory and proposed that a written agreement should be formed to formalize the deal. The Steering Committee began preparation of a Letter of Commitment (LOC) in June 2000. The draft was circulated for review in July 2000 and discussed at the August 1 Steering Committee meeting. By this point, ISSC had begun installing communications lines to regional agencies such as the MTA in Los Angeles. The LOC was revised in August and presented again at the September 5 Steering Committee meeting. The next nine months were characterized by prolonged negotiations between and among the Steering Committee members and ISSC, resulting in slow progress. By June 2001, although the LOC had not been signed, ISSC had installed the equipment necessary for the Kernels and verified that a "test network" was up and operating. Everything that ISSC was required to do to get the Kernels installed had been completed, and the network was ready for the Kernel servers to be connected. Although the "test network" is operational, negotiations regarding long-term sustainability of the "interregional backbone" are ongoing.

Lastly, the Kernel and its interface were designed and developed concurrently with several regional "Early Start" projects, as shown in Exhibit 10. The "Early Start" regional projects were hesitant to expend their limited resources designing their software systems to a Kernel design that they believed was a "moving target." This further contributed to delays and some frustration, and prompted two regional projects to take mitigating action:

- The TravelTIP project chose to develop its own "Kernel-lite," which provides some of the same services, but is not interoperable with the Showcase Network. Although the decision to create Kernel-lite allowed system development to continue unabated – and resulted in a partially operational system in September 2000 – neither the TravelTIP system nor any of the TravelTIP partners are currently connected to the interregional Showcase Network. Plans and cost estimates to undo TravelTIP's reliance on Kernel-lite and integrate the system with the interregional Kernel network are under development.

- The IMAJINE project took a three-month hiatus, as well as other periodic work stoppages in order to allow the Kernel to progress. IMAJINE was completed in November 2001, and its four partner agencies are the only ones currently integrated with Kernel version 1.0.

Exhibit 10 – Joint Timeline of the IMAJINE, TravelTIP and Kernel Early Start Projects



3.3.2 Impact of other Showcase Projects on Scoping & Design and the Kernel

Concurrent design and implementation of the Kernel and a few of the regional systems appears to have resulted in a better Kernel implementation.

It is not clear whether the Kernel could have been designed without the input of the "Early Start" regional projects. Although some stakeholders argue that the Kernel should have been designed and completed prior to the development of the regional systems that depend on it, that approach may have resulted in a Kernel that would not have met the needs of those regional systems. For example, the concurrent design of both the Kernel and regional systems helped identify the need for "fail-over" functionality.

Prior to inclusion of the "fail-over" requirement, each Kernel would have been dedicated to serve only the agencies in its region, and failure of a Kernel server would have caused the agencies in that region to experience at least a partial loss of service. There was no backup. However, with fail-over, the four Kernels were redesigned to "mirror" each other such that if one failed, any of the remaining three could be used as an alternate to restore full service. This is just one example of how concurrent development better defined system needs and influenced overall design of the integrated network of ITS projects.

4 Cost Evaluation

The cost evaluation draws information from documented costs and personal interviews. Budget information was taken directly from the project's contracts and amendments, while operations and maintenance costs were obtained from discussions with agency personnel. Informal interviews were conducted to verify information and fill in any "holes" that were discovered during analysis.

4.1 Constraints & Assumptions

There are two primary considerations for the cost evaluation:

- The project's cost is based on the fixed-price budget stipulated in the Scoping & Design contract and its amendments. The budget reflects what was paid by the client agency, but not necessarily the actual detailed costs of the goods and services that comprise the project and resulting system.

- Operations and maintenance (O&M) costs have been estimated based on available information and certain assumptions indicated later in this section.

4.2 Project Budget & Estimated Development Costs

This section addresses the project's contracted tasks and budget, as well as its role in supporting the Showcase Program's "design once, deploy many times" philosophy.

4.2.1 Project Budget

The Scoping & Design Project cost roughly $5 Million over 8 years.

Although one fixed price contract was utilized to design, build, and install the Kernel, the project was managed similar to a task order contract in which successive amendments added scope and provided additional fixed funding. The total cost of the project is estimated from the individual budgets of its four phases, which are shown in Exhibit 11.

Exhibit 11 – Total Budgets of the Four Kernel Phases

Phase	Contractor	Budget	Percentage
Phase 1	Rockwell/NET	$840,000	17%
Phase 2	Rockwell/NET	$1,454,984	29%
Phase 2a	Odetics/NET	$207,841	4%
Phase 3	Odetics/NET	$2,442,026	49%
		$4,945,032	100%

Each phase of the contract is broken down into more detail in Exhibits 12-15, which list each phase's tasks and the budget associated with each one. Since the contract was negotiated as fixed-price, the budgets shown in Exhibits 12-15 might not accurately reflect actual costs and expenditures.

Exhibit 12 – Scoping & Design Phase 1 Budget per Task

Task/Cost Item	Budget	%
Task A – Detailed Scope and Schedule	$6,960	0.8%
Task 1 – Early Start Candidate Report	$30,589	3.6%
Task 2 – System Architecture Report	$652,978	77.7%
Task 3 – Implementation Plan	$28,597	3.4%
Task 4 – Federal Funding Proposal	$30,027	3.6%
Task 5 – Federal Funding Presentation	$39,958	4.8%
Task 6 – Updated Work Plan and Schedule	$6,075	0.7%
Contingencies	$45,000	5.4%
Total	**$840,181**	**100.0%**

Exhibit 13 – Scoping & Design Phase 2 Budget per Task

Task/Cost Item	Budget	%
Task 7 – Detailed User Requirements	$221,072	15.2%
Task 8 – Detailed System Requirements	$232,041	15.9%
Task 9 – Candidate Architectures	$106,868	7.3%
Task 10 – High Level System Design	$147,172	10.1%
Task 11 – Kernel Design Document	$668,690	46.0%
Task 12 – Lancaster/Palmdale Corridor Expansion Presentation	$15,969	1.1%
Task 13 – Task 2-6 Reproduction/Distribution	$63,172	4.3%
Total	**$1,454,984**	**100.0%**

Exhibit 14 – Scoping & Design Phase 2A Budget per Task

Task/Cost Item	Budget	%
Task RP1.1/1.2.1 – Version 0.2 Functional Spec.	$95,653	46.0%
Task RP1.2.2 – Version 0.2 Disposition Matrix	$31,884	15.3%
Task RP1.2.3 – Quarterly Status Report	$2,500	1.2%
Task RP1.3.1 – Expersoft to Iona Technical Memo	$75,304	36.2%
Task RP1.3.2 – Monthly Status Report	$2,500	1.2%
Total	**$207,841**	**100.0%**

Exhibit 15 – Scoping & Design Phase 3 Budget per Task

Task/Cost Item	Budget	%
Task 14 – Development of Kernel v0.2	$396,620	16.2%
Task 15 – Delivery of Kernel v0.2	$65,262	2.7%
Task 16 – Development of Kernel v0.3	$496,050	20.3%
Task 17 – Delivery of Kernel v0.3	$75,468	3.1%
Task 18 – Update User Requirements	$117,951	4.8%
Task 19 – Develop Communications High Level Design	$99,726	4.1%
Task 20 – Develop Implementation Phasing Plan	$130,323	5.3%
Task 21 – Training/Acceptance Testing of Kernel v0.2/0.3	$210,000	8.6%
Task 22 – Deployment of Kernel v1.0	$550,800	22.6%
Task 23 – Project Management	$211,668	8.7%
Task 24 – Operations, Maintenance, and Warranty of Kernel v1.0	TBD	0.0%
Task 25 – San Diego Kernel Prototype Software Installation and Support	$8,163	0.3%
Task 26 – Acceptance Testing of Kernel v1.0	$79,995	3.3%
Total	**$2,442,026**	**100.0%**

4.2.1.1 Hardware Costs

Most of the hardware costs for the Kernel equipment were not available for this report; however, Exhibit 16 lists at least some of the hardware items procured by the project. The contracting agency, SANDAG, procured the hardware itself in order to save money on the Materials and Handling (M&H) fee often charged by contractors. The amount of the fee varies between contractors, but is typically on the order of 10% of the hardware purchase price. SANDAG followed its formal procurement process and obtained three qualified bids before making a final purchasing decision.

Exhibit 16 – Kernel Hardware Costs

Hardware Item	Quantity	Unit Cost*	Total Cost
HP K360 Kernel Server	4	$20,000 - $23,000	$80,000-$92,000
HP Entria II Operator Workstation	4	NA	NA
Kernel Mgt PC	4	$2,000	$8,000
17” color monitor for Operator Workstation	4	NA	NA
19” color monitor for Kernel Mgt PC	4	NA	NA
3COM 24-Port 10/100 Autoswitch/stackable	4	NA	NA
Cisco 1601 CSU/DSU Router	4	NA	NA
Cisco 4-Wire DSU WAN Interface	4	NA	NA

* Cost of a single server, workstation or monitor at time of purchase in 1999.

Most of the system’s hardware was procured just prior to – or early into – the project’s implementation phase so that the custom software could be developed directly on those machines. Although this approach greatly reduces the risk of hardware/software incompatibility

and helps ensure a successful software implementation, agencies should be aware that rapid advancement in technology could result in the hardware becoming obsolete prior to project completion. There is more discussion regarding planning for system upgrades in the section on Operations and Maintenance (O&M).

4.2.1.2 Software Costs

Software costs for the Kernel include both custom-developed software as well as licenses for commercial off-the-shelf (COTS) packages. The exhibits below contain an itemization of the COTS software costs. The total cost of the COTS software components used in the Kernel system is approximately $162,364.

Exhibit 17 – COTS Software on the Four Kernel Servers

Item	Quantity	Unit Cost*	Total Cost
English HP-UX CDE Runtime Environment - v10.20	4	$1,658	$6,632
Netstation Version 9.11 for /UNIX	4	$735	$2,940
Netstation CDE 2.0	4	$73	$292
Hardware Enablement and Critical Patches for HP-UX 10.20 Servers (6/99)	4	$0	$0
Orbix OTM, HP-UX 10.2 version 3.0.1	4	$11,000	$44,000
OrbixWeb, HP-UX 10.2 version 3.0	4	$2,995	$11,980
OrbixTrader, HP-UX 10.2 version 3.0	1 (4 CPU)	$20,000	$20,000
Openfusion-Trader, HP-UX 10.2 version 1.1.1	4	$0	$0
			$85,844

* Cost of a single server, workstation or monitor at time of purchase in 1999.

Exhibit 18 – COTS Software on the Four Kernel Workstations

Item	Quantity	Unit Cost*	Total Cost
RogueWave Threads.h++, HP-UX 10.20	4	$995	$3,980
RogueWave Tools.h++, HP-UX 10.20	4	$495	$1,980
RogueWave Standard C++ Library, HP-UX 10.20	4	No invoice	
HP aC++ (ANSI) Compiler, HP-UX 10.20	4	$1,089	$4,356
Sun Microsystems Java Development Kit (JDK)	4	No invoice	
			$10,316

* Cost of a single server, workstation or monitor at time of purchase in 1999.

Exhibit 19 – COTS Software on the Four Kernel PCs

Item	Quantity	Unit Cost*	Total Cost
Iona OrbixOTM, Windows NT 4.0	2 (2 CPU)	$7,500	$15,000
Iona OrbixWeb, Windows NT 4.0	4	$2,995	$11,980
Iona OrbixTrader, Windows NT 4.0	1 (4 CPU)	$20,000	$20,000
PrismTech's Openfusion Trader Version 1.1.1	4	$0	$0
Symantec VisualCafe, Prof. Edition, Windows NT 4.0	6	$269	$1,614
Microsoft Visual Studio, C++ Compiler, Windows NT 4.0	6	$1,445	$8,670
RogueWave Threads.h++, Windows NT 4.0	6	$995	$5,970
Tools.h++, Windows NT 4.0	6	$495	$2,970
Sun Microsystems Java Development Kit (JDK) version 1.1.7B for Windows NT	4	No invoice	
			$66,204

* Cost of a single server, workstation or monitor at time of purchase in 1999.

4.2.2 Design Once, Deploy Many Times

The Scoping & Design project made "design once, deploy many times" possible through the development of the Showcase Program's high-level Kernel-Seed architecture and the development of standardized objects and interfaces.

"Design Once, Deploy Many Times" is the Priority Corridor's philosophy for achieving cost efficiency through a modular system design, software re-use, and "economy of scale." In general, the Scoping & Design project supports and makes "design once, deploy many times" possible through the development of the high-level Kernel-Seed architecture and standard interfaces. Without a common standard for the Priority Corridor, each region (and possibly each system) would have to be specially integrated and tailored to fit within Showcase's "system of systems."

The Scoping & Design project further supports "design once..." through the development of four identical Kernel servers for the Priority Corridor's four regions. Theoretically, each region could have conducted its own independent Kernel development effort based on a common set of requirements. This approach, had it been taken, could have cost the Priority Corridor over four times as much money.

4.3 Estimated Operations & Maintenance (O&M) Costs

Whereas each region supports its own respective regional systems, Caltrans supports the Priority Corridor's interregional infrastructure, including the Kernels. Support of the Kernels could cost Caltrans as much as $177,000 to $300,000 annually.

4.3.1 Operations

The operations cost for the Kernel has been broken down into three contributing components: labor costs, utility costs, and office space costs. Each of these cost components applies in a varying degree to each project participant.

4.3.1.1 Labor

The Kernel is an enabling technology that supports other Showcase systems. Since it runs autonomously, there is no day-to-day labor cost for operations. This was an important, and successful, design feature of the system. Labor costs for Kernel maintenance are addressed separately in section 4.3.2.1.

4.3.1.2 Utilities

The Kernel's utility costs are for electricity (for powering the needed servers and workstations) and telecommunications (for interregional communications). Exhibit 20 estimates the additional annual electricity cost impact produced by Kernel hardware. These estimates are based on the following assumptions:

- An average electricity rate of $0.16 per kW-hour (the actual rate varies seasonally)
- Servers operate 24 hours per day, 365 days per year
- Usage of operator workstations, PCs and monitors is negligible.

Exhibit 20 – Estimated Marginal Annual Electricity Costs for the Kernels

Hardware Item	Model	Power Draw	Power Cost	Est. Annual Cost
4 Kernel Servers	HP K220	1250W	$0.16/kW-hr	**$7,008**

Telecommunications between the four Kernels makes up the greatest portion of the monthly operating cost. Each of the four Kernel servers resides in one of Caltrans' four Southern California TMCs, and Caltrans' statewide WAN provides the interregional connectivity between them (refer back to Exhibit 8). Although the WAN is operated and maintained by Caltrans HQIT, usage is not free of charge. Negotiations are ongoing as to how the Priority Corridor will fund its use of the WAN over the long-term.

Exhibit 21 – Monthly and Annual Telecommunications Costs for Interregional Network[4]

Description	Monthly Cost	Annual Cost
Use of bandwidth on the statewide WAN.	$10,000	**$120,000**

The costs for regional systems to connect to the WAN and the Kernels are covered by the regional agencies. As of the writing of this report, only the IMAJINE project partners are integrated with the WAN and Kernel v1.0. Please see the IMAJINE Evaluation Report for details of these costs.

4.3.1.3 Office Space

Caltrans reports no additional financial cost for the space occupied by the Kernel or its related equipment because there is no specific accounting down to the project or system level.

4.3.2 Maintenance

4.3.2.1 Labor

Caltrans estimates an annual cost of $50,000 for technical support and maintenance of the Kernel servers. This estimate does not include the potential cost for ongoing System Administration, which would cover configuration management, systems engineering support, and contract management for system upgrades. Such Systems Administration is estimated to cost an additional $125,000 annually[5].

4.3.2.2 Replacement Hardware/Software

As of the writing of this report, the Southern California ITS Priority Corridor Steering Committee is reviewing cost estimates for Showcase's first major system upgrade. The CORBA-based software developed for the Kernel, IMAJINE and TravelTIP is based on Iona's Orbix 3.x product, which Iona stopped supporting in early 2002 when it released its new Orbix 2000 product. Since Orbix 2000 is not backwards-compatible with Orbix 3.x, the Corridor faces a tough decision:

(1) Build the remaining regional systems using an unsupported software component (Orbix 3.x), or...

(2) Build the remaining regional systems using Orbix 2000 and go back and upgrade (rebuild) the systems that were recently completed (the Kernel, IMAJINE and TravelTIP), or

(3) Retire the Kernel servers and distribute the Kernel services to the regional systems using Orbix 2000.

The preference of the regional partners is to build their systems using the most up-to-date components, namely Orbix 2000. However, the use of Orbix 2000 in the regional systems will necessitate the use of Orbix 2000 in the Kernel to achieve interoperability. This has a further ripple effect in that Orbix 2000 requires the most recent HP operating system, which cannot run on the current Kernel hardware. Four new Kernel servers would have to be deployed. A recent Caltrans estimate for upgrading the Kernel (hardware and software) to use Orbix 2000 indicated a cost of approximately $1.8 million[6].

Long-term plans for the Showcase Network have always included that the Kernel services eventually would be fully distributed among the regional systems. A recent staff proposal suggests making this shift now. Corridor stakeholders are scheduled to debate this proposal in early 2003.

In summary, O&M of the Kernel Network in its current configuration could cost between $177,000 - $300,000. The differentiating factor is whether System Administration is handled corridor-wide or by the individual regions.

Cost Component	Regional System Admin.	Corridor-wide System Admin.
Electricity	$7008	$7008
WAN	$120,000	$120,000
Tech Support Labor	$50,000	$50,000
System Administration	$0	$125,000
Totals	**$177,008**	**$302,008**

5 Institutional Impacts Evaluation

5.1 Impacts to Operations and Maintenance Policies and Procedures

Caltrans hosts, operates and maintains the Kernels

Each of the four Kernels currently resides at the Caltrans TMC in its respective region. In May 2002, and in response to the efforts of the Corridor-wide Strategic Planning Project (CWSPP), the Priority Corridor Steering Committee requested that Caltrans accept responsibility for O&M of the Kernels and the interregional "backbone" network (currently provided by the Caltrans WAN). A whitepaper estimating the O&M costs of the Kernels and network was prepared and submitted to Caltrans management. A formal decision has not yet been made whether Caltrans will accept the responsibility.

5.2 Impacts to Staffing/Skill Levels and Training

Scoping & Design has had no impact to staffing or skill levels

Operation and maintenance of the Kernels has not impacted staffing or required skill levels. The Kernels were intentionally installed at the Caltrans TMCs in part due to the availability of technical staff with the appropriate skill sets.

Training

Training on administration of the Kernels was provided twice during the project: once for version 0.3 in June 2000, and again in early 2002 for version 1.0. The training was conducted at NET both times by a combination of NET and Iteris staff. Since the Kernels are installed at Caltrans TMCs, the trainees consisted of Caltrans TMC technical staff. The training covered:

General System Overview
- System/Project overview
- Terminology
- Workstation Environments (general)

System Administration
- Starting/Stopping the System
- System Monitoring
- Shutdown
- Publish & Subscribe Service
- Time Synchronization Service
- Naming Service
- Center Monitoring
- Add/Modify/Delete Center
- Center Join/Leave
- Security

System Maintenance
- Hardware Description
- Software Description
- Status of Maintenance Contracts

5.3 Impacts to the Competitive Environment

There is controversy over the accuracy and completeness of the Kernel documentation

The joint team of Iteris and NET developed the Kernels, and the system design is documented across many documents and hundreds of pages. As the project's contracting agency, SANDAG currently holds this documentation on behalf of the Priority Corridor, and may release it to subsequent contractors.

Competing contractors have argued that the documentation is inaccurate, incomplete, and, therefore, insufficient for anyone else to understand how to upgrade, modify, or integrate with the Kernels. Whether this is a valid complaint remains unconfirmed and requires further study. At most, validation of the documentation could require an examination of the Kernel software source code (excluding any third-party COTS source code that was used) to confirm such things as object definitions, event sequencing, etc.

5.4 Impacts to Local Planning Processes, Policy Development, and the Mainstreaming of ITS

The development of the Kernels puts in place both a physical and institutional foundation for further ITS development across Southern California.

Physically and institutionally, one of the greatest accomplishments of the Showcase Program is its development of system interface standards for the entire Priority Corridor. Similar to the national effort on NTCIP, adoption of these standards will help promote interoperable systems that enable greater information sharing, improved agency coordination, and reduced costs over time. Furthermore, the deployment of the regional network and several new agency centers (Remote Workstations) provides a foundation on which functions and services can be tested, analyzed, improved, and built upon.

Perhaps more importantly, the Kernels create an institutional foundation that helps to mainstream ITS across the Priority Corridor. Through this experience, stakeholders from the four regions have had the opportunity to face and resolve critical institutional issues and establish precedents for the Corridor's future ITS projects. Some of these critical issues include, but are not limited to:

- System and information security
- System reliability
- Policies regarding shared control of field equipment such as CCTVs and CMSs
- Software ownership and the treatment of intellectual property rights
- Delegation of operations and maintenance responsibilities (including funding).

These precedents will help clear the way for future ITS advancements in Southern California.

6 Traveler and Transportation Information Management Evaluation

6.1 Extent of Regional and Interregional Transportation and Traveler Information Integration Between Agencies

At this time, only the four IMAJINE project partners in Los Angeles County are integrated with Kernel version 1.0.

The Kernel is an enabling technology that provides "common services," as well as an interregional communications "backbone." As of the writing of this report, only the four IMAJINE project partners (MTA, Access Services Inc., City of South Gate, and Caltrans District 7) in the Los Angeles region are integrated with the Kernel version 1.0 and the Showcase Network. While the Kernel has been proven effective for meeting the data sharing needs of these agencies, it was designed with ample capacity to support many additional agencies.

6.2 Utilization of Regional and Interregional Transportation and Traveler Information by Public Agencies

Limited data is currently exchanged and used by the partners of the IMAJINE system. Efforts are underway to bring additional agencies onto the network, and the system is designed with this functionality and capability in mind.

7 Conclusions and Recommendations

The Showcase Program is an important part of Southern California's ongoing process to develop and deploy an integrated ITS infrastructure. Specifically, the Scoping & Design project provides all of Southern California with a common technical and institutional foundation on which to continue those ITS developments.

The Scoping & Design project represents a significant effort in planning, analysis, design and implementation. Through this effort, Southern California has reached consensus on a multi-regional ITS architecture that specifies the use of standard software interfaces and CORBA for interregional transportation data exchanges. Critical pieces of that architecture include the interregional Showcase Network and the Kernel software that helps manage the network and provides several necessary network services.

The Scoping & Design contract supported the first eight years of an ongoing evolutionary development of the Kernel software. Through an iterative process, the consultant team successfully developed and delivered a Kernel version 0.1 prototype, a version 0.2/0.3 prototype, and final Kernel version 1.0. The Kernel software resides on four identical and redundant servers. There is one Kernel Server in each of Caltrans' four Southern California Transportation Management Centers (TMCs). Negotiations to use the Caltrans Wide Area Network (WAN) to provide the necessary interregional communications between these servers are ongoing.

Although the Kernels are functional, they are currently in limited use. Due in part to the rapid advancement in software technology between 1995-2001, certain third-party COTS software components used in the Kernel software are no longer supported by their vendor. This presents a dilemma for the Priority Corridor as additional regional systems – being designed and built today using more recent technology – consider how (or whether) to integrate with a Showcase infrastructure based on older technology. As the steward of the four Kernels, Caltrans is working with the Priority Corridor stakeholders to identify and research possible solutions and identify potential funding sources to update the system. Since there will be an ongoing need for occasional system upgrades, particularly as related to software platforms, agencies should consider planning and budgeting for these as part of their routine operations and maintenance (O&M).

The Scoping & Design project also exemplifies the scheduling dilemma facing many ITS projects. Although the actual software development and installation of the Kernels was accomplished in roughly 36 months, the time required by the stakeholders to plan, design, document, and reach consensus on the system amounted to nearly six years. For software projects, this can be an eternity as technology advancements quickly outpace them. To help alleviate schedule impacts, agencies might consider two complementary strategies for managing future ITS projects.

First, split the Design and Build phases into separate contracts or task orders so that planning can take place independent of system development. The Design phase provides

time for stakeholders to reach consensus on needs and system requirements, develop a detailed Concept of Operations, and put in place the necessary institutional agreements to help ensure the system's successful and continued operation once built. Although combining the Design and Build phases into a single Design-Build contract eliminates the burden of executing the Build contract on its own, the cost (i.e., the risk associated with committing to build a system before the needs or institutional issues are fully understood) does not necessarily outweigh this benefit.

Second, agencies should consider planning and deploying their systems in small steps, which can be implemented quickly and do not commit the agency to large technology investments. This approach provides flexibility through the recurring opportunity to reevaluate investment decisions and technology choices after each incremental build.

In summary, the development of the Kernels put in place both a physical and institutional foundation for further ITS development across Southern California. Through this experience, stakeholders from the four Southern California regions have had the opportunity to face and resolve critical institutional issues and establish precedents for the Priority Corridor's future ITS projects. The programming of funds for continued operations and maintenance of Showcase systems demonstrates the Southern California Priority Corridor's commitment to mainstreaming ITS.

Endnotes/References

[1] ISTEA requires that "operational tests utilizing federal funds have a written evaluation of the Intelligent Vehicle Highway Systems technologies investigated and the results of the investigation." Although Showcase is not officially an operational test, it deploys and demonstrates ITS services, functions, and technologies under "real world" conditions, similar to an operational test.

[2] California Statistical Abstract, Table B-4. California Department of Finance, Sacramento, CA. October 2001.

[3] California Statistical Abstract, Table J-4. California Department of Finance, Sacramento, CA. October 2001.

[4] Showcase Completion White Paper, Caltrans, July 2002.

[5] Showcase Completion White Paper, Caltrans, July 2002.

[6] Showcase Completion White Paper, Caltrans, July 2002.